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HYDROELASTICITY: AN ANNOTATED BIBLIOGRAPHY

SPECIAL BIBLIOGRAPHY
SB-62-10

APRIL 1962

NOTICE

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Compiled by
GEORGE R. EVANS

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Lockheed

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SUNNYVALE, CALIFORNIA

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ABSTRACT

Hydroelasticity per se is a relatively new science; however, many of its theories are a continuation and ramification of the older science of aeroelasticity.

It is defined as the phenomenon involving interactions among inertial, hydrodynamic and elastic forces. When all three of the phenomena are involved simultaneously, the resulting action is said to be dynamic; when only two of the three phenomena are involved simultaneously, the result is defined as static.

The existence of hydroelasticity is confined to the mutual interactions of two or three of the above phenomena.

Search Completed February 1962

SOURCES CHECKED

The search extended from 1948 - February 1962, however; only several references were found prior to 1959.

In addition to using the facilities of the Technical Information Center, Lockheed Missiles and Space Co. and ASTIA, the following indexes and abstracts were checked:

Aerospace Engineering Index

Applied Mechanics Review

Engineering Index

IAS Abstracts

Also, because of there being relatively little information published on the subject, inquiries were directed to several institutions and organizations for aid in obtaining information. They were:

California Institute of Technology
Hydrodynamics Laboratory

Massachusetts Institute of Technology
Hydrodynamics Laboratory

The Society of Naval Architects and
Marine Engineers. Panel H-8 (Hydroelasticity)

Stevens Institute of Technology
Davidson Laboratory

TABLE OF CONTENTS

1. Abramson, H.N.

STUDIES OF HYDROELASTICITY. Southwest Research Inst., San Antonio, Tex. Final rept. 1 Jan 58-31 Mar 60, 8p. (Contract Nonr-247000) ASTIA AD-237 756

Summaries are given for the following papers: A discussion of the flutter of submerged hydrofoils, An alternative formulation of the problem of flutter in real fluids, Effect of the free surface on the flutter of submerged hydrofoils, A note on panel flutter as a problem in hydroelasticity, and An exploratory flutter analysis of the fairwater planes of SSN 585 (SKIPJACK).

2. Abramson, H.N. and Chu, W.H.

A DISCUSSION OF THE FLUTTER OF SUBMERGED HYDROFOILS. Southwest Research Institute, Dept. Engng. Mech. TR1, Aug 58, 33p.

Available data relating to flutter in high density fluid media are analyzed. It is stated on the basis of this meager material that rather serious discrepancies exist between theory and experiment. Several possible reasons for this disagreement are examined in some detail, e.g. influence of hydrodynamic load on vibration modes, influence of viscous effects by modifying the Kutta condition, tunnel-wall interference, etc., but none of them alone gives a sufficiently good improvement. It is concluded that until additional experimental data are available, the prediction of flutter in high density fluid media should be approached with care.

3. Abramson, H.N. and Chu, W.H.

A NOTE ON PANEL FLUTTER AS A PROBLEM IN HYDROELASTICITY. Southwest Research Inst., San Antonio, Tex. Technical rept. no. 4, 5 Oct 59, 9p. (Contract Nonr-247000) ASTIA AD-229 363

3. (cont'd) The present state of knowledge concerning the aeronautical problem of subsonic panel flutter is discussed briefly, followed by some speculations relative to the application and importance of this information to hydroelastic problems.

4. Aero-Hydro-Elasticity-Structural Mechanics. In PROCEEDINGS OF FIRST SYMPOSIUM ON NAVAL STRUCTURAL MECHANICS. Pergamon Press, New York, 1960.

5A. Baird, E.F., Squires, C.E., Jr. and Caporali, R.L. AN EXPERIMENTAL AND THEORETICAL INVESTIGATION OF HYDROFOIL FLUTTER. IAS 30th Annual Meeting, New York, N.Y., 22-24 Jan 62, Paper 62-55, 28p.

Navy-supported experimental investigation of the flutter characteristics of hydrofoils. The variation of flutter speed with sweep, immersion depth, and mass-density ratio is studied. Experimentally determined flutter speeds are compared with theoretical results based upon existing flutter-analysis methods, and it is shown that a modal type of analysis holds considerable promise for the prediction of low-mass-density-ratio flutter.

5. Arnold, L., Lane, F. and Slutsky, S. PROPELLER SINGING ANALYSIS. General Applied Science Labs., Inc., Hempstead, N.Y. Final rept. Technical rept. no. 221, 1961, 69p. (Contract Nonr-274500) ASTIA AD-257 424

A theoretical investigation is presented of the phenomenon of singing of moving hydrofoil vanes or blades. The experimentally noted dependence of Strouhal frequency on blade thickness, boundary layer thickness and vibration amplitude is taken into consideration in formulating an expression for the

5. (cont'd) hydrodynamic forces acting on the blade. The unsteady hydrodynamic forces associated with an oscillating blade are generalized by relinquishing the Kutta condition of boundedness of pressure jump at the blade trailing edge. Curves of frequency and amplitude versus velocity were obtained which bear good qualitative resemblance with available experiment. The effect of trailing edge thickness is also examined and indicates frequency and amplitude effects consistent with experiment. The sound field intensity and distribution is discussed and an estimate obtained.

6. Benjamin, T.B.

EFFECTS OF A FLEXIBLE BOUNDARY ON HYDRODYNAMIC STABILITY. Aeronautical Research Council, Gt. Brit. ARC rept. no. 22267; FM 3009 (in cooperation with Cambridge Univ.) 22 Sep 60, 20p. ASTIA AD-247 643

A generalized linear hydrodynamic stability theory is presented for the flow past a flexible boundary, whose response to travelling sinusoidal pressure waves can be represented by a complex coefficient. A simple correction with the theory for a rigid wall is established, allowing existing results to be used. Three modes of instability are discussed, and alternative criteria are proposed as a basis for the design of flexible surfaces to stabilize laminar flow.

7. Blokh, E.L.

HORIZONTAL HYDRODYNAMIC IMPACT OF A SPHERE IN THE PRESENCE OF A FREE LIQUID SURFACE. Space Technology Lab., Inc., Los Angeles, Calif. Rept. no. STL-TR 61-5110-4, Jan 61, 27p. (Trans. from Prikladnaya Matematika i Mekhanika, Tom v. 17, 1953 by Z. Jakubski) ASTIA AD-264 149

7. (cont'd) The problem of motion of a solid body floating on the surface of an incompressible liquid or on the surface of a liquid partly filling a shell is considered as a problem of hydrodynamic impact of a solid body against an incompressible liquid in those cases, in which this motion undergoes very high accelerations within a sufficiently short period of time. The investigation of horizontal impact is much more complicated than that of a vertical impact because the latter comes to the problem of a smooth flowing around a body entirely enveloped by a liquid. The simplest case of a three-dimensional horizontal impact, i.e., when the solid body is a sphere half immersed in a noncompressible liquid or a spherical shell half-filled with liquid is investigated.

8. Blokh, E.L.

HORIZONTAL IMPACT ON AN ELLIPSOID OF REVOLUTION ON AN IDEAL LIQUID HAVIN G A FREE SURFACE. Space Technology Labs., Inc., Los Angeles, Calif. Rept. no. STL-TR 61-5110-5, Jan 61, 39p. (Trans. from Prikladnaya Matematika i Mekhanika, Tom v. 17, n. 6, 1953) ASTIA AD-264 152

This analysis is an immediate continuation of the preceding paper in which the horizontal hydrodynamic impact of a sphere was examined. The impact represented the simplest case of the three-dimensional problem of a horizontal impact on a solid body in an ideal liquid having a free surface. As the investigation of all these cases is conducted by a general and sufficiently uniform method, this analysis presents a detailed solution of the outer problem of an oblate ellipsoid of revolution only; for all other cases, however, only the final results are given together with the minimum of necessary explanations.

9. Borg, S.F.

The analysis of ship structures subjected to slamming loads. J. SHIP RES. v. 4, n. 3, p. 11-27, Dec 1960.

9. (cont'd) Paper describes an interesting fundamental study of various phases of response of a simplified ship structure to slamming-type loads. Great stress is placed upon phenomenological considerations. It is distinguished between three time regions: period of localized effect, of transition, and of over-all effect. It is assumed that velocity of travel of stress or displacement effects is 10,000 fps as an average. Calculations are based on energy considerations. Different damping losses are discussed; internal friction in steel only (and rivet-slip in riveted ships) is concluded to be important. Scaling factors involved in vibrational damping are also discussed and it is shown possible to simultaneously satisfy all dynamic scaling parameters developed. Author proposes an approximate analysis of ship hulls subjected to slam loads. In the first place stresses are assumed to be within elastic range. Analysis is concerned with responses in only two of the above time regions, namely period of transition and of over-all effect. For period of transition method of solution is based upon wave-transmission characteristics of ship hull; a shear-bending wave travels down the length of ship and introduces balancing inertia forces and shear deflection only as bending deflection has no time to develop. This is equivalent to the "shudder" of ship. For period of over-all effect, method of solution is based upon energy considerations. As loading remains constant, strain energy in quasi-statically loaded beam equals vibrating energy in vibrating beam, damping included. When computing vibratory energy author considers 2- and 4-node symmetrical and 3- and 5-node antisymmetrical modes of vibration. Only bending energy due to inertia forces are considered. Available experimental evidence is stated to suggest that the major 2-node mode predominates, which means that slam loads were applied very close to bow end or higher modes were quickly damped out. Results of computations are compared with earlier works and are considered at least as reasonable as earlier results. A consideration of vibrating beam with rectangular cross section in elastoplastic range concludes the paper.

10. Bottaccini, M.R. and Nicholaides, J.D. (eds) C

(CLASSIFIED TITLE) Bureau of Ordnance Hydroballistics Advisory Committee, Washington, D.C. NAVORD rept. no. 3533, 1954, lv. ASTIA AD-151 983. CONFIDENTIAL REPORT

11. Chu, W.H. and Abramson, H.N.

EFFECT OF THE FREE SURFACE ON THE FLUTTER OF SUBMERGED HYDROFOILS. Southwest Research Inst., San Antonio, Tex. Technical rept. no. 3,

11. (cont'd) 12 Sep 58, 29p. (Contract Nonr-247000)

ASTIA AD-204 679

Expressions for the unsteady lift and moment acting on an oscillating hydrofoil submerged under a free surface are derived by an extension of classical unsteady thin airfoil theory. The method of images is employed to account for the free surface, but the additional contribution resulting from surface waves, considered small, is neglected. The results of flutter computations are presented for a hypothetical example, using a simple representative station analysis, for ratios of depth of submergence to semi-chord of two and infinity; it is found that the lower flutter speed corresponds to infinite depth of submergence.

12. Chu, W.H. and Abramson, H.N.

HYDRODYNAMIC THEORIES OF SHIP SLAMMING. REVIEW AND EXTENSION. Southwest Research Inst., San Antonio, Tex. Technical rept. no. 1, 2 Nov 59, 1v. (Contract Nonr-272900)

ASTIA AD-234 154

A critical review and evaluation of existing hydrodynamic theories of body-water impact is presented. It is shown, partly by comparison with available data, that fitting methods are adequate only for bodies of reasonably large deadrise angle during later stages of the impact process. The ellipse-fitting technique is extended to a much broader class of body forms and more accurate formulations of the general problem are proposed that avoid linearization of the free surface boundary condition and can account for compressibility effects during the initial stage of impact, although numerical procedures must be employed.

13. Cummins, W.E.

FORCES AND MOMENTS ACTING ON BODY MOVING IN ARBITRARY POTENTIAL STREAM. U.S. Navy Dept., David W. Taylor Model Basin. Rept. no. 780, June 53, 57p.

Approach of Lagally is used, which considers boundary condition at surface of body to be established by means of system of singularities within body; this

13. (cont'd) result is rederived and extended to case in which body is subject to arbitrary nonsteady motion including rotation in stream changing with time; force and moment are found to be "Lagally force and moment" plus additional components.

14. Cummins, W.E.

HYDRODYNAMIC FORCES AND MOMENTS ACTING ON SLENDER BODY OF REVOLUTION MOVING UNDER REGULAR TRAIN OF WAVES. U.S. Navy Dept., David Taylor Model Basin. Rept. no. 910, Dec 54, 33p.

Forces and moments for case where body moves with constant linear velocity under sinusoidal train of waves oblique to its course; body is represented by system of singularities, and dynamic effects evaluated by extension of Lagally's theorem; forces and moments are given explicitly as functions of sectional area curve of body; application to seaworthiness.

15. Dressler, R.F.

(APPLIED MATHEMATICS) STUDIES IN HYDROFOILS AND ELASTICITY. Contract performed for the Office of Naval Research by the National Bureau of Standards, 1955.

16. Duffin, R.J.

THE MAXIMUM PRINCIPLE AND BIHARMONIC FUNCTIONS. Carnegie Inst. of Tech., Pittsburgh, Pa. Technical rept. no. 45; CIT-ORD-6D-TR45; OOR rept. no. 223.49, 11 Nov 60, 11p. (Contract DA 36-061-ORD-490, Proj. TB2-0001(223)) ASTIA AD-248 714

16. (cont'd) The maximum principle which applies to solutions of partial differential equations of elliptic type are considered. This principle asserts that the maximum of a solution occurs on the boundary of a region. Consideration of the ratio of solutions of an elliptic equation shows that the ratio satisfies the same maximum principle. This result is then used to obtain a maximum principle relating to biharmonic functions. These maximum principles give inequalities which biharmonic functions must satisfy. The relations and concepts have application in elasticity and in hydrodynamics.

17. Eagleson, P.S., Huval, C.J. and Perkins, F.E. TURBULENCE IN THE EARLY WAKE OF A FIXED FLAT PLATE. Massachusetts Inst. of Tech., Hydrodynamics Laboratory. (Sponsored by the Bureau of Ships, David Taylor Model Basin.) Rept. no. TR-46, Feb 61.

18. Edge, P.M., Jr. HYDRODYNAMIC IMPACT LOADS OF A -20° DEAD-RISE INVERTED-V MODEL AND COMPARISONS WITH LOADS OF A FLAT-BOTTOM MODEL. National Advisory Committee for Aeronautics, Washington, D.C. Technical note TN 4339, Aug 58, 36p. ASTIA AD-200 911L

Available to U.S. Military Organizations. Others submit requests via National Advisory Committee for Aeronautics, Wash. 25, D.C. Hydrodynamic-impact-loads data were obtained at the Langley impact basin from tests of a narrow-beam model. Fixed-trim impacts were made in smooth water over a range of landing conditions at a beam-loading coefficient of 19.15, with a few impacts at beam-loading coefficients of 27.90 and 36.07. Loads, moments, motions, and bottom pressures were measured throughout for each of the impacts. The maximum impact loads for the inverted-V model are compared with loads obtained for a flat-bottom model.

19. Edge, P.M., Jr. and Mason, J.P.

HYDRODYNAMIC IMPACT LOADS ON 30° AND 60° V-STEP PLAN-FORM MODELS WITH AND WITHOUT DEAD RISE. National Advisory Committee for Aeronautics, Washington, D.C. Technical note TN 4401, Sep 58, 20p. ASTIA AD-204 449L

Available to U.S. Military Organizations. Others submit requests via National Advisory Committee for Aeronautics, Washington 25, D.C. Hydrodynamic impact loads of 30° and 60° included-angle V-step models were investigated at the Langley impact basin. The investigation consisted of a series of fixed-trim impacts in smooth water with a dead-rise model having a round keel and chine flare and a beam-loading coefficient of 3.6. Impact loads and motions for a range of trim and flight-path angles were measured to determine effects of step plan-form angle and for comparison with data for a flat-bottom model. The data are presented in a table, and typical time histories and variations of maximum impact lift and maximum draft with trim and flight-path angle are included. Over the range of the tests the maximum loads for the 30° V-step model are shown to be as much as 29 percent less than those for the 60° V-step model. Effects of dead rise for the 30° V-step model are shown to indicate that this configuration experiences loads as small as 50 percent of those experienced by a similar V-step flat-bottom model.

20. Eisenberg, P.

Research trends in naval hydrodynamics--ONR Program. J. SHIP RESEARCH v. 2, n. 1, p. 3-7, June 1958.

Scope, orientation, and motivation of work at Office of Naval Research; program of research on turbulence, boundary layers, boiling and cavitation, and waves; hydrodynamic noise; ship wave and viscous resistance, seaworthiness and stability; ship, underwater body, and air flight missile propulsion; exit of submarine launched missiles, and weapon effects; water based aircraft; hydrofoils and hydrofoil boats; breakwaters.

21. Friswell, J.K., Kurn, A. and Ridland, D.M.

INVESTIGATION OF HIGH LENGTH/BEAM RATIO SEAPLANE HULLS WITH HIGH BEAM LOADINGS. HYDRODYNAMIC STABILITY. PART 2: THE EFFECTS OF CHANGES IN THE MASS, MOMENT OF INERTIA AND RADIUS OF GYRATION ON LONGITUDINAL STABILITY LIMITS. Aero. Res. Counc., London. Curr. paper 202, 1955, 14p.

Tests have been performed to ascertain the effects of varying load, moment of inertia, and radius of gyration on the stability limits of a high length-to-beam-ratio dynamic model. The tests were carried out at high beam loadings, with C_{Δ_o} in the range 2.00-3.00. A theoretical analysis has been made of the relation between the effects of the various parameters, and the results of the analysis compared with experimental results. The effect on the limits of a change from a velocity to a draught base has also been considered. It has been found that the load is the most critical factor, and that, provided the load is kept constant, increasing the moment of inertia has little effect on the limits. Good agreement has been found between theoretical treatment and experiment.

22. Gesswein, B.H. and Moses, F.

CALCULATED MODES AND FREQUENCIES OF HULL VIBRATION OF USS GEORGE WASHINGTON (SSBN 598). David W. Taylor Model Basin. Rept. 1464, Nov 60, 23p.

Normal mode shapes, natural frequencies, and bending moments of vertical flexural vibration and of longitudinal bar-type vibration of the hull and of the shafting system were calculated for USS GEORGE WASHINGTON (SSBN 598). The methods used in evaluating the parameters necessary for the calculations are described.

23. Golovato, P.

A STUDY OF THE FORCES AND MOMENTS ON A HEAVING SURFACE SHIP. David Taylor Model Basin, Washington, D.C. Research and development rept. no. 1074, Sep 57, 35p. ASTIA AD-144 902

A surface ship model was constrained to perform forced heaving oscillations in still water and the resulting lift forces and pitching moments obtained. The influence of forward speed, frequency and amplitude of oscillation were investigated. The added mass and damping of the ship motion were determined as well as the coupling moments (the pitching moments due to heaving velocity and acceleration). Comparisons are made between the various theoretical prediction procedures and these experimental results. The significance of the observed nonlinear damping forces is discussed.

24. Goodman, T.R. and Sargent, T.P.

LAUNCHING OF AIRBORNE MISSILES UNDERWATER. PART X. TOTAL STATISTICAL MISSILE RESPONSE TO CONFUSED DIRECTIONAL SEAS. Allied Research Associates, Inc., Boston, Mass. Document ARA-947, 15 Aug 61, 22p. (Contract Nonr-234300) ASTIA AD-261 457

In launching an airborne missile from underwater, both the launching submarine and the missile itself respond in a random fashion to the waves of a confused sea. The submarine motion contributes to the trajectory of the missile by imposing a set of random initial conditions on the missile. The resulting missile response, subject to both random forcing functions and random initial conditions, is then determined by employing the technique of generalized harmonic analysis. The response resulting from the forcing function alone, called the direct response, has been determined previously; the response resulting from the initial conditions alone, called the indirect response, has also been determined. The particular feature of this report is the inclusion of responses resulting from the statistical cross-correlation between direct and indirect responses. It is shown, furthermore, that there is no cross-correlation between the initial conditions resulting from submarine roll and the other wave-induced causes of missile response.

25. Grim, O.

Calculation of hydrodynamic forces caused by oscillation of ship hulls. JAHRB. SCHIFF-BAUTECH. GESELLSCH. v. 47, p. 277-299, 1953. (In German)

Analysis of vertical and horizontal oscillations of two-dimensional ship hulls. Potential ϕ at water motion composed of that of (1) oscillation in unlimited water, (2) reversed pressure of foregoing at water surface, (3) periodical pressures of $A_n\phi_n$ at water surface within region of ship which, choosing A_n, author adapts to satisfy boundary conditions at ship's surface, exactly in district points of section or with least squares errors. Also a more rough and simple method of approximation is presented. Considering two-dimensional results applicable at every section of three-dimensional ship, author calculates combined heaving and pitching and--more briefly--combined lateral oscillation and rolling, and compares with experiments. Results are presented in graphs. Good agreement is found--somewhat astonishing with regard to idealized conditions but promising for practical value of method, if confirmed.

26. Hannum, L.A.

DYNAMIC STRENGTH OF SHIPS. Aerojet-General Corp., Frederick, Md. Final rept. no. LR 13373, 29 July 57, 58p. (Contract NObs-72170) ASTIA AD-155 101

A study was made (1) to establish and solve the hydroelastic equations of motion of a ship in the presence of waves, (2) to reduce this solution to a step-by-step computation formulation suitable for use by the ship designer, and (3) to compare the dynamically computed stresses with those obtained from static calculations. Three basic problems were considered: (1) the evaluation of the various terms and coefficients which depend on complicated ways on the hull shape and submergence, (2) the treatment of nonlinearities and other complexities of the hydrodynamic problem so as to render the problem tractable without invalidating the results, and (3) the solution of the elastic equation with its complicated variable coefficients. The method developed for treating the elastic problem was such that the equations of motion of the ship as a rigid body were obtained by merely taking the zero-order solution of the general problem. The complete system of the ship as an elastic body coupled to the water is first introduced. Certain simplifications and

26. (cont'd) approximations are employed, but the derived equation of motion is complete. The method for solving the equation of the total motion is valid, in principle, for any case which satisfies the conditions of the problem being considered. The procedure permits a first-order evaluation of the principle mean stresses and moments without consideration of the elastic structure of the ships. The elastic properties enter into the calculation as factors in the higher-order approximations which are presented in step-by-step fashion.

27. Heller, S.R. and Abramson, H.N.

Hydroelasticity: A new naval science.

AMERICAN SOCIETY OF NAVAL ENGINEERS,

JOURNAL p. 205-209, May 1959.

Presents aeronautical background; defines various terms used; i.e., Buffeting, gusts, loads, etc. Hydroelasticity is defined as the phenomenon involving interactions among inertial, hydrodynamic and elastic forces. When all three of the phenomena are involved simultaneously, the result is defined as dynamic; when only two of the three phenomena are involved, the resulting action is said to be static. The existence of hydroelasticity is confined to the mutual interactions of two or three of the above mentioned phenomena.

27A. Henry, C.J.

HYDROFOIL FLUTTER PHENOMENON AND AIRFOIL

FLUTTER THEORY. IAS 30th Annual Meeting,

New York, N.Y., Paper 62-54, 22-24 Jan 62.

Application of aeroelastic procedures to predict the flutter speed of a rigid hydrofoil that has two degrees of freedom. The results are compared with experimental measurements and certain discrepancies in flutter speed are noted at low-density ratios.

28. Henry, C.J., Dugundji, J. and Ashley, H.

Aeroelastic stability of lifting surfaces

in high-density fluids. J. SHIP RES. v. 2,

n. 4, p. 10-21, Mar 1959.

Limited amount of flutter tests at low values of the structural to fluid mass ratio are reviewed. It appears that flutter instability is unlikely for the

28. (cont'd) low mass ratios typical of underwater hydrodynamic operations, although divergence remains a possibility. A parametric study of the effect of the mass ratio, for a special example and following standard procedure, shows that flutter will become milder at the lower mass ratios and eventually ceases to occur. Much of the paper is designed to introduce conventional flutter analysis to naval architects.

29. Imlay, F.H.

THE COMPLETE EXPRESSIONS FOR ADDED MASS OF A RIGID BODY MOVING IN AN IDEAL FLUID.

David Taylor Model Basin, Washington, D.C.

Rept. no. 1528, July 61, 22p. ASTIA AD-263 966

Expressions are given for the complete added mass effect for any rigid body moving in any manner in an ideal fluid. The expressions give the force and moment acting on the body in terms of 21 added mass derivatives. These derivatives are the maximum number that are independent for a Cartesian set of body axes. Reduced expressions are also given for a finned prolate spheroid with the origin of the body axes located at some point on the axis of revolution. Theoretical values of the added mass derivatives are given for an ellipsoid and a prolate spheroid when the reference axes are principle axes for an origin located at the center of the ellipsoid or spheroid. The added mass effect for a stationary body in an accelerating fluid is also described.

30. Ippen, A.T., Toebes, G.H. and Eagleson, P.S.

THE HYDROELASTIC BEHAVIOR OF FLAT PLATES AS INFLUENCED BY TRAILING EDGE GEOMETRY. Hydrodynamics Lab., Mass. Inst. of Tech., Cambridge. Technical rept. no. 36, Apr 60, 105p.

(Contract Nonr-184121, Proj. NS 715-102)

ASTIA AD-236 070

Results are presented of a theoretical review and an experimental investigation of the hydroelastic vibration of thin flat plates suspended at zero mean angle of attack in a fluid stream. The review indicated that recognized

30. (cont'd) experimental facts such as the influence of trailing edge geometry and the three-dimensional wake structure were inadequately related to theoretical considerations about the vibration phenomenon. The experimental investigation consisted of a detailed determination of the amplitude and frequency spectra of the vibration on a number of flat test plates which were mounted in the test section of a water tunnel at zero mean angle of attack. The effects on the vibrational behavior of trailing edge geometry, geometric and elastic properties of the plate support, free stream velocity and ambient pressure were explored experimentally. An equation of motion was written for the test plate - torsion spring system employed. Results of a qualitative analysis of this non-linear equation are compared with the experimental results obtained.

31. Jaeger, H.E.

The determination of the scantlings of plates loaded by water-pressure or subjected to the combined action of water-pressure and compressive forces in their middle plane.

INTER. SHIPBLDG. PROGR. v. 3, n. 23, p. 349-366, July 1956.

Contents of paper have appeared also in Bulletin technique du Bureau Veritas, Feb. 1954, and in Schip en Wer/Oct. 22, 1954. Author gives curves according to Timoshenko and to Schade for deflection and stresses in unstiffened and stiffened rectangular plates subjected to uniformly distributed load. Curves are commented on briefly. Limits to theory of plates are discussed. When lateral load is combined with compressive forces in plane of plate, utilization of curves and of a magnification factor according to Bleich is described. Reviewer finds that use of a reduced magnification factor when deflection exceeds half plate thickness is restricted to simply supported plates and not, as author states, to plates with clamped edges. The mistake is evident and appears also by comparison with Bleich's work(Buckling Strength of Metal Structures, N.Y., McGraw Hill, 1952, 508p.) from which author has taken some part of the material. Some remarks concerning influence of water pressure upon critical (buckling) stresses are also given. A useful paper.

32. Jasper, N.H. and Brooks, R.L.

SEA TESTS OF THE USCGC UNIMAK. PART 2. STATISTICAL PRESENTATION OF THE MOTIONS, HULL BENDING MOMENTS, AND SLAMMING PRESSURES FOR SHIPS OF THE AVP TYPE. David Taylor Model Basin, Washington, D.C. Research and development rept. no. 977, Apr 57, 43p. ASTIA AD-144 898

The motions and hull-girder bending moments which a ship of the general form and size of the AVP10 class may be expected to experience over a wide range of operating conditions are presented in statistical form. The data are based on extensive measurements made on the USCGC UNIMAK during sea trials in the North Atlantic Ocean. The methods of statistics have been employed in the planning of the at-sea phases of the trials and in the collection, analysis, and presentation of the large amount of data. From the test results, data are derived for this type of ship for use in design and operating problems involving bending moments, hull motions, and slamming pressures. Formulas are given for use in estimating probable maximum values of moments and motions.

33. Jewell, D.A.

A note on hydroelasticity. J. SHIP RES. v. 3, n. 4, p. 9-12, Mar 1960.

Henry, C.J., et al, Aeroelastic stability of lifting surfaces in high-density fluids. J. SHIP RES. v. 2, n. 4, p. 10-21, Mar 1959 indicates that flutter is unlikely for values of "mass ratio" less than 1, and that most hydrofoils have "mass ratios" of about $\frac{1}{2}$ as compared with 50 for airfoils. This article points out that in special cases (for example, where a ship participates in the motion) a large "mass ratio" can be obtained. It also points out that existing flutter theory deviates from experimental results when the reduced frequency K is greater than 0.4 and that a typical value of K for a surface ship is 2.0. Other factors peculiar to hydrofoil flutter are noted and the importance of further analytical and experimental investigations is emphasized.

34. Kaplan, P. C

THE HYDRODYNAMIC FORCES AND MOMENTS, INCLUDING THE MAGNUS FORCES AND MOMENTS, ACTING ON A SPINNING MISSILE, AS DETERMINED FROM UNDERWATER ROTATING ARM EXPERIMENTS (U). Experimental Towing Tank, Stevens Inst. of Tech., Hoboken, N.J. Rept. no. 667, Oct 57, lv. (Contract NOrd-16193) ASTIA AD-149 722. CONFIDENTIAL REPORT

35. Kaplan, P. and Henry, C.J.

A study of the hydroelastic instabilities of supercavitating hydrofoils. J. SHIP RES. v. 4, n. 3, p. 28-38, Dec 1960.

Theoretical study deals with two-dimensional case of rigid foils on elastic support; static (torsional divergence) and dynamic (bending torsion flutter) instabilities are investigated using hydrodynamic results obtained mainly by M. Tulin and L.G. Woods. The influence of variations of several problem parameters is determined mainly for zero cavitation number 6; in addition conditions at low 6 are hypothesized. Contrary to fully wetted flow, both static and dynamic instabilities may occur at relevant density ratios. Experimental check is recommended because of hypotheses assumed.

36. Kaplan, P., Hu, P.N. and Tsakonas, S.

METHODS FOR ESTIMATING THE LONGITUDINAL AND LATERAL DYNAMIC STABILITY OF HYDROFOIL CRAFT. Experimental Towing Tank, Stevens Inst. of Tech., Hoboken, N.J. Rept. no. 691, May 58, lv. (Contract Nonr-26314) ASTIA AD-161 149

36. (cont'd) The equations of motion of tandem hydrofoil craft in both longitudinal and lateral modes, each mode having three degrees of freedom, are derived on the basis of the linear theory of small disturbances. Various stability derivatives appearing in the equations are determined in terms of the lift and drag forces acting at the foils, together with their derivatives with respect to angle of attack and depth. Various theoretical and experimental methods for determining these hydrodynamic quantities are discussed in the report. Stability criteria for both the longitudinal and lateral dynamic stability of hydrofoil craft also are presented. The results may be used for estimating the dynamic stability of hydrofoil craft while in the preliminary design stage, and it is expected that the equations are sufficiently accurate to indicate the trends in the degree of dynamic stability as changes are made in the design configuration.

37. Khaskind, M.D.

Approximate methods for the determination of the hydrodynamic characteristics of ship oscillations. IZV. AKAD. NAUK SSSR OTD. TEKH. NAUK n. 11, p. 66-86, Nov 1954.

Paper is an attempt to summarize and to complete author's earlier theoretical and experimental work on ship oscillations (title source no. 7-8, 1942, no. 11-12, 1942, n. 10, 1946; PRIK. MAT. MEKH. v. 10, n. 1, 1946, v. 17, n. 2, 1953, v. 17, n. 3, 1953, v. 18, n. 1, 1954). Vertical and lateral translatory oscillations and rotations about all three ship axes are considered. As an oscillating ship hull, which is moving obliquely against plane sinusoidal waves, can be divided into three groups. The first group contains forces and moments due to forced oscillations of the ship in translatory motion on a calm water surface, and in the second there are the well-known restoring moments and forces due to the static stability and buoyancy of the ship. The third group comprises disturbing forces and moments caused by waves on a nonoscillating hull in steady motion, and can be divided into two classes, the first of which consists of forces which are caused by undisturbed waves, and the second of forces caused by wave diffraction. The first group of forces and moments is characterized by the generalized coefficients of the entrained mass and of damping. They depend on the frequency of forced oscillations of the ship, but are nearly independent of the traveling speed for sufficiently slender hull forms. Using certain theoretical results of his earlier work and assuming simplified forms for ship sections, author derives approximate expressions for these coefficients in the case of infinitely slender hulls and indicates how the finite hull length can be taken into account. The disturbing forces and moments due to waves without taking into account wave diffraction can be determined by the theory of A.N. Krylov. Earlier obtained forms for the velocity potential allow derivation and discussion of approximate formulas for these forces and for those caused by wave diffraction as well.

38. Krzywoblocki, M.Z.

DETERMINING AIR REACTIONS ON MOVING VEHICLES. PART III. METHODS OF HYDRODYNAMICS. Institute for System Research, Univ. of Chicago, Ill. WADC technical rept. no. 56-51, pt. 3, July 59, 208p. (Contract AF 33(616)5689) ASTIA AD-227 138

The most important methods of hydrodynamics are described to calculate the forces and moments acting on a body moving in a fluid which is at rest or on a body at rest in a moving fluid. Only the most distinguished features of each method are presented. The work is divided into two parts: incompressible and compressible fluids. A separate list of references and separate numeration of equations are included. All the methods discussed have mathematical justification and no approximative assumptions of an intuitive nature are introduced.

39. Leehey, P. and Steele, J.M., Jr.

EXPERIMENTAL AND THEORETICAL STUDIES OF HYDROFOIL CONFIGURATIONS IN REGULAR WAVES. David Taylor Model Basin, Washington, D.C. Rept. no. 1140, Oct 57, 37p. ASTIA AD-151 412

This report presents a comparison of the experimentally measured and theoretically predicted values of the heave and pitch responses of area stabilized hydrofoil configurations to regular waves and to transient pulses. The theoretical responses were computed from the equations given by Weinblum in "Approximate Theory of Heaving and Pitching of Hydrofoils in Regular Shallow Waves," TMB Report C-479. Curves of heave and pitch amplitude magnification and phase lag are given as functions of wavelength. The approximate linearized theory is found to give a qualitatively correct prediction of resonance and orbital motion effects. The theoretical amplitude magnifications are greater than the measured ones for most conditions, particularly for heave in following seas. This is believed to be caused principally by the neglect of nonlinear

39. (cont'd) terms in the equations of motion. A Mid-foil can be used with a tandem Vee-foil to cancel heave response to following seas of wavelength approximately equal to the outer foil spacing.

40. Lueck, J.H.

APPLICATION OF SUPERCAVITATING HYDRO-FOILS TO HIGH PERFORMANCE SEAPLANES. PART II. STEADY STATE HYDRO-DYNAMIC LOADS CALCULATIONS. Dynamic Developments, Inc., Babylon, N.Y. Rept. no. 108, Mar 58. Decl. 9 July 58, 1v. (Contract Nonr-238700) ASTIA AD-200 362

This report presents a method and data for rapid prediction of optimum lift/drag ratios and associated design lift coefficients values for supercavitating hydrofoils applicable to high speed seaplane design. Hydro-dynamic loads pertain to both surface piercing and fully submerged hydrofoils of arbitrary planform. Supercavitating hydrofoils, of suitable configuration, exhibit lift/drag ratios which are considered high enough to warrant the use of such foils on high performance seaplanes. This is true even after allowance is made for an adequate design airplane trim variation which would result in foil angle of attack changes above and below normal design operating angles of attack. A hydrodynamic loads comparison between various supercavitating foil bottom shapes is given for an example main hydrofoil chosen as suitable for a general seaplane with a 150,000 lb. take off gross weight, a hull clearance speed of 65 knots and a take off speed of 200 knots. For particular surface piercing hydrofoils, a comparison is given between experimental and theoretical predictions of loads and minimum angles of attack for full foil ventilation.

41. McGoldrick, R.T.

RUDDER-EXCITED HULL VIBRATION ON USS FORREST SHERMAN (DD 931) (A PROBLEM IN HYDROELASTICITY). David Taylor Model Basin, Washington, D.C. Rept. no. 1431, June 60, 47p. ASTIA AD-240 379

41. (cont'd) The vibration phenomenon on USS Forrest Sherman (DD 931) was quite unlike the usual cases of ship vibration in that the hull was set into a three-noded horizontal vibration whose frequency remained constant over a considerable range of speed. The Boston Naval Shipyard traced this vibration to the twin rudders and eliminated it by reversal of the rudder toe-angle setting. No simple explanation of the phenomenon was apparent at the time of its occurrence, but it appeared that any mechanism producing such a condition would neccessarily involve hydroelastic effects. This problem falls within the spheres of interest of both the Hydroelasticity Panel of the Hydrodynamics Committee and the Hydro-Structure Vibration Panel of the Hull Structure Committee. While officially the project was handled under strictly naval jurisdiction, these panels maintained an interest in its progress because of representation of the David Taylor Model Basin in their memberships. The author explores several conceivable explanations, and, while acknowledging contrary opinions, accounts for the phenomenon as due to a sub-critical control-surface flutter condition.

42. McGoldrick, R.T.

SHIP VIBRATION. David Taylor Model

Basin, Washington, D.C. Rept. no. 1451,

Dec 60, 245p. ASTIA AD-259 466

Details are given on the general subject of ship vibration, including both the structural and hydrodynamic phases of the subject. Brief mention is also made of vibration in the propulsion system. Procedures for dealing with the problem of ship vibration in the design stage are suggested. An introduction to hydroelasticity is included.

43. McGoldrick, R.T. and Jewell, D.A.

A CONTROL SURFACE FLUTTER STUDY IN THE

FIELD OF NAVAL ARCHITECTURE. David

Taylor Model Basin. Rept. no. 1222,

Sep 59.

43A. Munshtukov, D.A.

Priblizhennoe modelirovanie flattera

kryla v gidrolotke. AVIATSIONNAIA

TEKHNIKA n. 3, p. 16-21, 1960. (In

Russian)

Investigation of the flutter of hydrofoils, establishing an anology between the flutter behavior of hydrofoils and that of airfoils. Also considered is the nonstationary open flow of liquid generated by the oscillations of a cylindrical body. The particular type of flutter, in which an interaction of bending and torsional vibrations of the profile is observed, is analyzed; the conditions for simulating in the seaplane vibrations of a profile which, by its inertia and elastic characteristics, represents an airfoil, are established; and it is shown that the gas hydraulic analogy can be used to obtain qualitative results clarifying the effect of various factors and parameters on the bending torsional flutter of an airfoil.

44. Nott, J.A.

STATIC TESTS OF A CW-351 SONAR DOME

UNDER SIMULATED HYDRODYNAMIC LOADING.

David Taylor Model Basin, Washington,

D.C. Rept. no. 1492, July 61, 23p.

ASTIA AD-261 493

Structural tests were conducted on a CW-351 sonar dome by simulating the steady-state hydrodynamic forces encountered in a seaway by multiple static loads in the laboratory. Computed steady-state hydrodynamic forces for angles of yaw of 0 deg and 10 deg and for ship speeds up to 35 knots were simulated and applied to the sonar dome. In large areas of the dome, stresses were relatively low. The areas of high stress were at the juncture of the bottom and sides of the dome. Nowhere did the measured stresses exceed the yield strength of the material. The tests indicate that, for domes not subjected to appreciable slamming forces, reinforcement could be more effectively distributed and a lighter dome of adequate strength would still result.

45. Parkin, B.R., and Kermeen, R.W.
Water tunnel techniques for force measurements on cavitating hydrofoils.
J. SHIP RES. v. 1, n. 1, p. 36-42, Apr 1957.

Paper reviews briefly the experimental techniques and data-correction procedures developed in connection with studies in the High Speed Water Tunnel, California Institute of Technology, for hydrofoil force measurements. The matters discussed relate chiefly to problems of force measurement in cavitating flow and to procedures devised to solve them. Items considered in this connection are water-tunnel balances, the effects of tip-clearance flows, tare corrections, the importance of cavity-pressure measurements, cavitation scaling, tunnel-wall effects, and hydroelastic effects.

46. Perkins, F.E. and Eagleson, P.S.
THE DEVELOPMENT OF A TOTAL HEAD TUBE FOR HIGH FREQUENCY PRESSURE FLUCTUATIONS IN WATER. Massachusetts Institute of Technology, Hydrodynamics Laboratory. (Sponsored by the Bureau of Ships, David Taylor Model Basin) Rept. no. TN-5, July 59.

47. Perkins, F.E., Eagleson, P.S. and Ippen, A.T.
HYDRO-POWER PLANT TRANSIENTS. PART I. DESIGN OF A COMPREHENSIVE FIELD TEST PROGRAM. Massachusetts Institute of Technology, Hydrodynamics Laboratory. (Sponsored by the U.S. Army, Corps of Engineers, Omaha District) Rept. no. TN-7, Jan 61.

48. Sherman, F.S. (ed)

SYMPOSIUM--NAVAL HYDRODYNAMICS.

Washington, D.C. National Academy

of Sciences - National Research Council

Publication 515, 1957, 444p.

This book includes the papers and discussions presented at the Symposium on Naval Hydrodynamics held in September 1956. The material includes surveys and original contributions in most fields of hydrodynamics which are of interest to the naval scientist, engineer and architect. The contributors are outstanding authorities, and with the associated discussions have prepared treatments of the subjects which present the state of the science at the time the papers were given.

49. Sizov, V.G.

The stability of ships carrying granular

cargos. SUDOSTROENIE n. 6, p. 7-11, 1958;

REF. ZB. MEKH. n. 11, Rev. 13533, 1959.

The circumstances are investigated which occur when static and dynamic moments come into action in a ship carrying cargo of a granular type, and the influence of these moments on the stability of the ship is indicated. A simplified scheme is adopted for the shifting of the granular load, which enables the problem to be solved by the use of elementary methods. It is assumed that: (1) for every cargo of granular material there is a corresponding constant angle of rest, by which is meant the largest angle of slope for the surface of the cargo at which the material remains at rest;(2) sliding of the cargo follows its inclination so that the surface of the load when sliding occurs is inclined the whole of the time to the horizon at the angle of rest. Cases are examined when the pitching moment gives rise to angles of pitch smaller or greater than the angle of rest. The deduction is made that if the angular amplitude of the tossing of the ship exceeds the angle of natural slope then the effect of the granular cargo will be that of a stabilizer of the ship. The shifting of the center of gravity of the cargo and the relation to the angle of slide, as also the shoulder of the heeling pair because of the sliding of the cargo, are determined graphically. The worst case of all--the case of the action of the heeling moment toward the residual angle--is taken to judge the stability of the ship. The smallest dynamic moment required to make the ship capsize is determined by the constructed diagram of stability. It is necessary to establish the magnitudes of the angles of rest for various granular cargos in

49. (cont'd) different sets of conditions, to develop the character of the sliding of granular cargos and to determine the declination from the plane surface of the oversliding of the cargo.

50. Stevens Institute of Technology, Davidson Lab.
HYDROFOIL FLUTTER PHENOMENON AND AIRFOIL FLUTTER THEORY. VOL. I: DENSITY RATIO.
DL rept. R-856, Sep 61.

51. Toebes, G.H., Perkins, F.E. and Eagleson, P.S.
DESIGN OF A CLOSED JET, OPEN CIRCUIT WATER TUNNEL FOR THE STUDY OF WAKE MECHANICS. Massachusetts Institute of Technology, Hydrodynamics Laboratory. (Sponsored by the Bureau of Ships, David Taylor Model Basin.) Rept. no. TN-3, Apr 58.

52. Young, N.O., Goldstein, J.S. and Block, M.J.
The motion of bubbles in a vertical temperature gradient. J. FLUID MECH. v. 6, n. 3, p. 350-356, Oct 1959.

It has been observed experimentally that small bubbles in pure liquids can be held stationary or driven downward by means of a sufficiently strong negative temperature gradient in the vertical direction. This effect is demonstrated to be due to the stresses resulting from the thermal variation of surface tension at the bubble surface. The flow field within and around the bubble is derived, and an expression for the magnitude of the temperature gradient required to hold the bubble stationary is obtained. This expression is verified experimentally.

53. Yeh, G.C.K. and Martinek, J.

ANALYTICAL STUDIES ON SHIP SLAMMING. SLAMMING DUE TO PURE PITCHING MOTION WITH CONSIDERATION OF THE ELASTICITY OF THE SHIP. Reed Research, Inc., Washington, D.C. Final rept. 31 Dec 58, 26p. (Contract Nonr-248600) ASTIA AD-226 124

Procedures for numerical computations on pure pitching motion of an elastic ship is presented. After the motion and the pressure distributions of a rigid ship are obtained, the overall elastic deformations is estimated by considering the ship to be a free-free beam of variable mass and flexural rigidity along the length. The local elastic deformations is estimated by considering the ship bottom to be a rectangular plate with various boundary conditions. The motion and the pressure distributions of the elastic ship (whose shape continuously changes with time) replaced at each instant by an equivalent rigid ship can again be computed by the same method. This process can be repeated until the desirable degree of approximation is obtained.

SUBJECT INDEX

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SOURCE OR AGENCY INDEX

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ADDENDUM

The following citations are included as alternative sources for reports and articles listed in the bibliography:

Abramson, H.N.
A discussion of the flutter of submerged hydrofoils. JOURNAL OF SHIP RESEARCH v. III, n. 2, Oct 1959.
(Refer to Citation No. 2, Page 1 for Abstract)

Abramson, .
A note on panel flutter as a problem in hydro-elasticity. JOURNAL OF SHIP RESEARCH v. 3, n. 4, Mar 1960.
(Refer to Citation No. 3, Page 2 for Abstract)

Chu, W.H. and Abramson, H.N.
Effect of the free surface on the flutter of submerged hydrofoils. J. SHIP RES. v. 3, n. 1, p. 20-27, June 1959.
(See Citation 11, Page 6 for Abstract)

Kaplan, P. and Henry, C.J.

A STUDY OF THE HYDROELASTIC INSTABILITIES OF SUPERCAVITATING HYDROFOILS. Stevens Inst. of Tech., Davidson Laboratory. DL-Rept. no. R-838, Feb 60.

(Refer to Citation 35, Page 17 for Abstract)